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THE STEM NEMATODE TYLENCHUS DIPSACI ON WILD HOSTS IN THE NORTHWEST.

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INTRODUCTION.

Attention has been called several times to the occurrence of the stem and bulb infesting nematode *Tylenchus dipsaci* Kühn (*Tylenchus devastatrix* in most of the European literature) on various hosts in America. Byars (*1*)[1] mentioned its occurrence on hyacinth. Smith (*9*) and Byars (*2*) reported diseases in red clover and strawberry due to the organism. McKay dealt more at length with the disease in strawberry (*5*) and later reported its occurrence on alfalfa (*6*) and wild strawberry, *Fragaria chiloensis* (*7*). Godfrey (*3*) mentioned its occurrence on all the known hosts in America and briefly described the symptoms. This paper deals with the wide occurrence of the pathogen on the wild strawberry and reports an additional host, the false dandelion, *Hypochaeris radicata.* The discovery of the disease on this plant was made by Prof. H. P. Barss and the junior writer together, at Newport, Oreg., in June, 1922. *H. radicata* is listed by Massalongo (*4*, p. 8) as being subject to a nematode gall referred to as a "Helminthocecidium," which, judging from the illustration, is clearly the same as the one discussed here.

SYMPTOMS.

The symptoms of the disease on the wild strawberry (Pl. I, *A*, *B*, and *C*) are in every respect the same as on the cultivated. Swellings

[1] The serial numbers (italic) refer to "Literature cited" at the end of this bulletin.

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occur on leaves, stolons, and flower pedicels, and even in the flowers and fruits themselves. In the leaves the swellings may be in the petioles, either basally, intermediate, or involving the blade. They vary greatly in size, but are often several times the diameter of the leaf stem. The gall on the petiole is spindle shaped as a rule and often an inch or more in length. The swellings in the leaf blades are characteristically crinkled thickenings of greater or less extent, sometimes but not always made more prominent by a reddening against the green background. The leaf symptoms are not likely to be confused with those of any other disease.

The stolon symptoms are like those on the petioles. A swelling may be anywhere on the stolon, even on its tip. (Pl. I, *B*.) This undoubtedly is a factor in its distribution, the new plant in this case being affected at the outset. Fruiting stems are sometimes badly affected. Usually the galls occur most prominently as long club-shaped swellings just below the blossoms. Often the parts of the calyx or even the petals and receptacle are greatly enlarged and distorted. Fruits in all stages of maturity are sometimes irregularly swollen.

In Hypochaeris the symptoms as seen in the summer and fall consist mainly of swellings in the leaves, as they lie in a rosette on the ground. They are often distorted and twisted abnormally, especially when the gall is in the midrib. (Pl. II.) Here, as in the strawberry, a reddish coloration is sometimes evident on the leaves, but this is not the rule. Evidences of typical galls in flower stems were found as well, in the form of slight increases in thickness at their bases. Stem galls produced by an insect (*Aulax hypochoeridis* Kieff) were observed quite frequently also and should not be confused with the nematode swellings. The insect galls as a rule are much larger and more spongy in texture than those produced by the nematodes. Thanks are due to Dr. E. P. Felt, New York State, entomologist, and to L. H. Weld, of the Smithsonian Institution, Washington, D. C., for identification of the insect.

THE CAUSAL ORGANISM.

Examination of the typical swellings and galls invariably disclosed the presence in them of Tylenchus. Those from the strawberry had already been authentically identified as *Tylenchus dipsaci*. The Hypochaeris nematode appeared identical in every way with that found in alfalfa, clover, and strawberry and was so determined. Our identification was later verified by Dr. N. A. Cobb, nematologist, at Washington, D. C., who reported only a slight and insignificant variation in measurements from the other strains.

DISTRIBUTION.

The information on distribution included herewith, as well as on environmental relations, dissemination, etc., was derived principally from special survey trips made by the writers separately during the summers of 1921 and 1922. In addition, the Oregon State Board of Horticulture, prompted by the seeming advisability of conducting an eradication campaign, made an independent survey in the summer

of 1922. While these surveys were not by any means exhaustive, they covered typical localities and a considerable range of territory.

The results of the various surveys indicate that the stem nematode occurs definitely on one host or the other throughout practically the entire length of the Oregon coast line and in at least Pacific County in Washington. In addition, it occurs inland in Willamette Valley at various points. The southern limit is not definitely known for either host. On *Fragaria chiloensis* it is abundant in Coos County and also from there northward to the northern end of Tillamook County, where it apparently ceases. *Hypochaeris radicata* was found to be affected in the southern part of Lincoln County and northward, beyond the range of the diseased wild strawberries, into Washington. It was also found at Hillsboro, St. Joseph, McMinnville, and Corvallis, Oreg.[2] At the last point it occurred in considerable abundance on the campus of the Oregon Agricultural College. Material from this source was used for photographs (Pl. II) and for preserving. Cultivated strawberry fields were found infested to an extent that was of rather serious economic importance in Coos and Lane Counties and to a minor degree at Corvallis in Benton County. The distribution of the disease on its various hosts is shown on the map. (Fig. 1.)

FIG. 1.—Map of western Oregon and southwestern Washington, showing the distribution of the stem nematode (*Tylenchus dipsaci*) on cultivated strawberries (○), on wild strawberries (●), and on the false dandelion (×).

APPARENT INDEPENDENCE OF THE TWO HOSTS.

During the course of these surveys several interesting facts were brought out in connection with an apparent lack of any correlation

[2] During the summer of 1923 the nema disease was found in *Hypochaeris radicata* in great abundance at different points on Puget Sound, Wash., throughout the length of Willamette Valley, Oreg., and southward along the coast as far as San Francisco, Calif.

whatever between the two hosts, in so far as occurrence of the disease was concerned.

At various places along the shore line between Waldport and Newport, Oreg., a distance of approximately 20 miles, the disease was found on both Fragaria and Hypochaeris, both of which grew in abundance. At times where the two plants were closely associated both were found affected, and again one or the other or both were free. In some spots either host growing by itself was affected and at other times free from infection. In fact, infested areas were, as a rule, in spots. The plants on one strip of considerable extent might be 50 per cent and even occasionally 100 per cent infested, while those on another strip a short distance away would be entirely free or possibly less than 1 per cent affected.

At Newport a search was made for the disease in several small patches of cultivated strawberries within the town and in its suburbs. No diseased plants were found, however, in spite of the fact that Hypochaeris was found diseased quite frequently in strawberry patches. In one case a diseased plant of Hypochaeris was found in actual contact with the crown of a cultivated strawberry plant, which itself was not affected.

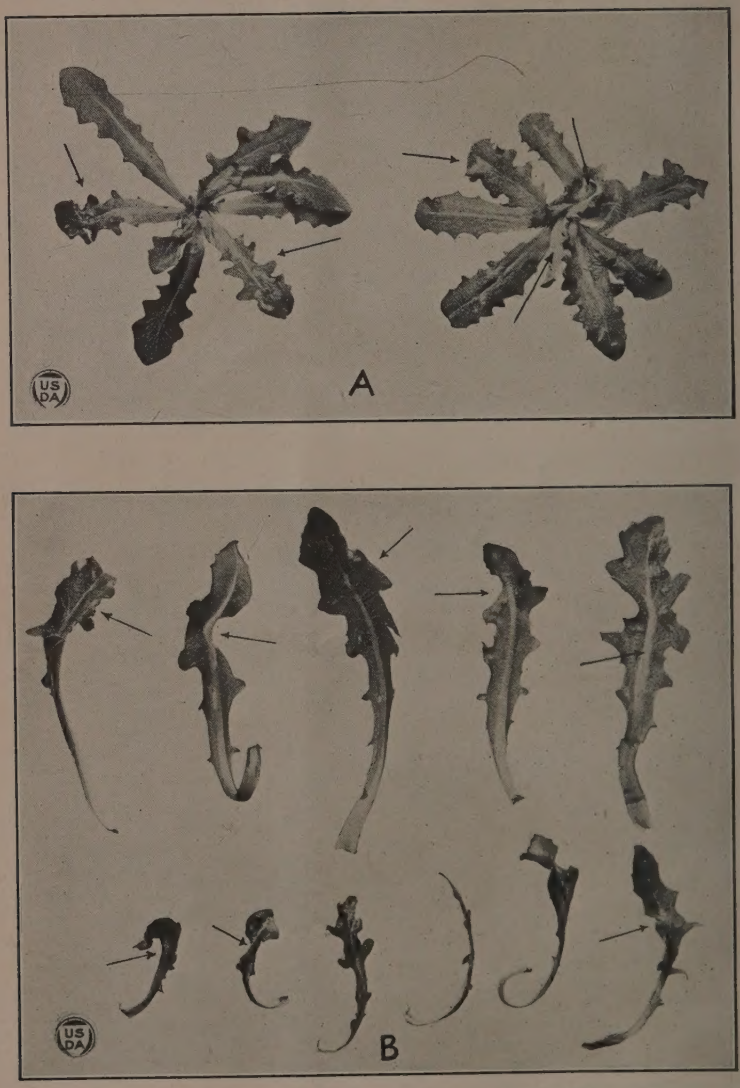
Likewise, in Tillamook and vicinity plants of Hypochaeris were found affected. Cultivated strawberry fields were observed and examined carefully, but not a trace of the disease was found. Wild-strawberry plants at this place, which is 5 miles from the coast, were examined but found free from infection.

Along the Tillamook County beach the disease was found scatteringly on the wild strawberry, in some places 75 per cent of the plants being affected; in others, none or comparatively few. Hypochaeris was also quite frequently diseased, some areas one-fourth of a mile from the shore being found in which 75 per cent of the plants were affected. Such spots were rare, however. In fact, many areas were examined during the course of the surveys in which not a trace of the disease was to be found. Here, too, occasional beds of cultivated strawberries were observed and found to be free from the disease.

In the vicinity of Seaside, Oreg., and thence northward it was observed that the stem nematode occurred on Hypochaeris, but was not to be found on Fragaria. Seaside is separated from the Tillamook Beach region, where the strawberry disease occurred abundantly, by a natural barrier consisting of a high promontory which was heavily forested. For several miles this host does not grow. This natural barrier may be an explanation for the absence of the disease beyond. Between the Tillamook Beach and Seaside Hypochaeris was rather rare, but such plants as were observed were free from the disease. Great open meadows in which both Hypochaeris and *Fragaria chiloensis* grew abundantly occurred near Gearhart. Many infested Hypochaeris plants were found here, but the Fragaria was always free from the nematode. Along the edge of the golf links at Gearhart a similar condition existed. Occasional diseased Hypochaeris plants were likewise found at the branch agricultural experiment station at Astoria, Oreg. Along the coast line north and south of Long Beach, Wash., the disease was found in considerable abundance on Hypochaeris, but the wild sand strawberry was entirely free from infection. Not a trace of the disease could be

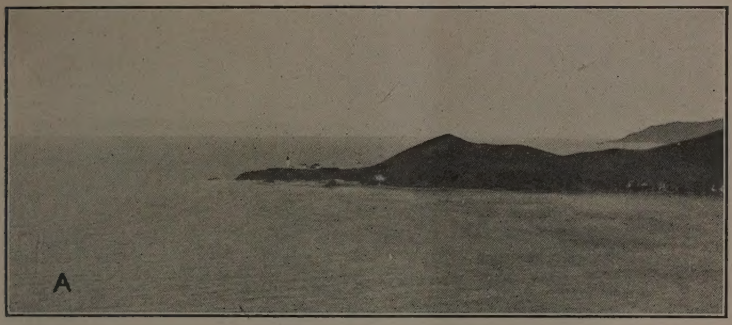
EXAMPLES OF NEMATODE INFESTATION.

A, Symptoms of the stem-nematode disease in the wild strawberry (*Fragaria chiloensis*). Note the swollen and distorted leaf blades and petioles. *B*, A new plant of wild strawberry developing on a runner which is badly swollen, due to nematode infestation. *C*, A wild strawberry leaf showing the upper and lower surfaces, with typical swellings caused by the stem nematode. *D*, Red-clover seedlings infested as a result of inoculation with the strawberry strain of *Tylenchus dipsaci*.



ROSETTES AND LEAVES OF FALSE DANDELION.

Arrows indicate the more striking points of infestation by the stem nematode: *A*, Two small "rosettes" of the false dandelion (*Hypochaeris radicata*) twisted and deformed owing to infestation. *B*, Leaves of *Hypochaeris radicata*, showing infestation.



SITES OF AFFECTED STRAWBERRY BEDS.

A, Yaquina Head, near Newport, Lincoln County, Oreg. The entire north face of the hill back of the lighthouse is covered with plants of *Fragaria chiloensis*, a large proportion of which are attacked by the stem nematode, *Tylenchus dipsaci*. *B*, Bluff at Seal Rocks, south of Newport, Oreg. On top of this bluff are beds of the wild sand strawberry severely attacked by *Tylenchus dipsaci*. *C*, A small bed of wild strawberries on the gradually sliding slope of the bluff on the north side of the hill shown in *A*. About 10 per cent of these plants are affected.

found in cultivated strawberries in northwestern Oregon or in Washington.

Quite frequently a large association of plants was found with the Fragaria or Hypochaeris, including the salal (*Gaultheria shallon*), the brake (*Pteris aquilina*), a moss, and a large number of small herbaceous flowering plants. All of these plants were carefully examined without finding any sign of the disease.

RELATION TO ENVIRONMENT.

In the case of Fragaria, nearness to the ocean appeared to be a factor which influenced infection. In most cases no disease was found 100 yards from the shore, even though it was abundant at the edge of vegetation above the beach. Quite frequently this host growing in the sand about the driftwood was affected. Again, frequently the sea side of a sand dune would have affected plants, while those on the land side would be free. Slopes near a rocky promontory upon which the waves dashed at high tide were often heavily infested. This was the case at Seal Rocks, in Lincoln County, at which point wild-strawberry patches quite extensive in area on a bluff 50 feet high were found more than 50 per cent affected with the nematode disease. (Pl. III, *B*). At Yaquina Head (Pl. III, *A*), where meadow grasses and strawberries predominate, the disease was found in great abundance, especially on the steep north slope of the hill. Over the entire slope from the beach to the summit, probably 500 feet high, diseased plants were found. Plate III, *C*, shows a view of a typical spot on the hillside where the disease was found.

A similar condition of a high percentage of diseased plants in strawberry meadows near the shore existed at another promontory known as "Jump-off Joe." Diseased plants occur close to the beach and on the side of the bluff to the very top. None was found, however, back of the edge of the bluff, a distance of 50 feet.

In many cases it appeared that almost constant high humidity was required to maintain infection and favor the spread of the disease on this host. This was obviously obtained at times by actual salt spray from the ocean and again from the heavy fog that occurs so frequently near the coast. When the photograph reproduced in Plate III, *B*, was taken, the atmosphere was saturated by a falling mist that nearly shut the distant rocks from view.

Nearness to the ocean did not appear to be a factor in the case of Hypochaeris. At Newport, where the plant grew abundantly as a weed in meadows, on lawns, and beside the streets, the disease was found for several hundred yards back into the town. It also occurred some distance from the shore in Tillamook County, Oreg., and near Long Beach, Wash. The presence of the infested Hypochaeris plants a considerable distance from the shore led to the search for and discovery of the disease at the inland valley points, where direct influence of ocean moisture could be no factor in infection.

ORIGIN AND DISSEMINATION OF THE DISEASE.

The possibility of the infection of the wild-strawberry plants having originated in the cultivated fields was at first considered

as not impossible. The infested patches first seen were close by the outlet of Siltcoos Lake, which lies about 4 miles distant, in the midst of the cultivated area. Diseased cultivated plants might conceivably have gotten into the lake and been carried down the stream. Becoming stranded, they might then have been blown or otherwise carried to the spots where the disease was observed. The abundance of the disease in remote places and in spots not easily reached in this way, however, would seem to be negative evidence. For example, a high percentage of diseased plants occurred on a sand hill about 50 feet high which was covered with vegetation.

In the light of later observations, especially, the possibility of infection having spread from cultivated fields does not seem very great. On the contrary, the results of the survey seemed to indicate that the disease has been present on the wild plants for many years and that it is passing to the cultivated strawberries. The following few cases may be mentioned specifically as apparent illustrations:

A grower living in Bandon, Oreg., set out young strawberry plants from Portland, where the disease is not known to occur, in the spring of 1920. No trouble was noticed until late in the growing season, when the nematode disease was found affecting a few plants. By October, 1921, 25 per cent of the original plants and quite a number of young plants started from the old ones were found diseased and had been pulled out and burned. The disease was found in abundance on wild strawberries within 50 feet of the cultivated patch and from there on for a distance of 2½ miles, which was as far as the search was continued.

Another grower, living just outside Bandon and within 200 yards of the ocean beach, obtained plants in 1919 from a grower in Bandon. The nematode disease developed quite heavily on this planting the first season, and in 1920 it became so severe that the entire patch was plowed up and planted to other crops. The wild-strawberry plants in the pasture adjoining, and even inside of the fence surrounding this patch, were extensively affected by the nematode disease. A visit to the patch of cultivated strawberries in town from which this planting had been started failed to reveal any evidence of the nematode disease among them, nor had the grower ever noticed any malady of the sort.

Still another grower had in 1919 moved a strain of strawberries from a farm a few miles east of Bandon, where it had been maintained for eight years without any evidence of the nematode disease, to another farm 4½ miles south of Bandon and 1½ miles back from the ocean beach. In 1920, the next season after the strawberries were moved to the new location, a slight amount of injury from the nematode disease was noticed, and in 1921, 2 per cent of the plants were rather severely affected. No wild strawberries were known to be near the berry patch east of Bandon, although they were quite numerous in the region of the farm south of town. The nematode disease has been found quite abundantly on wild strawberries at a point 3 miles from this farm. No examinations for the disease on the wild plants have been made closer to the farm than this, though there is every possibility that it does occur on the wild plants very much nearer to this farm.

Certain unusual observations related to the dissemination of the disease may be worthy of record. A plant of *Fragaria chiloensis* was

occasionally found growing entirely by itself, isolated by several feet from any others. Frequently such isolated plants were diseased as badly as those found in close association in thick beds. In one spot near Newport, Oreg., scattered diseased plants were found at the lower edge of a thick growth of salal (*Gaultheria shallon*) on the face of a perpendicular bluff. Similarly with Hypochaeris, a single diseased plant was found growing in a small pocket of soil at the edge of a jagged rock more than 4 feet distant from any other vegetation.

Nothing is known as to the chief agencies for the distribution of this disease among wild plants. Besides the gradual spread through runners or stolons, which occurs with strawberries, animals, birds, wind, water, etc., readily occur to the mind as possible agencies of dissemination. But even with these and other means active in helping to spread the pest, it seems entirely unlikely that it could have reached its present distribution during the time that it has been known to occur on the cultivated plants in the same region. In fact, as previously mentioned, the evidence seems to point to the conclusion that the pest has been present on the wild plants for many years and that it is now passing, in some localities at least, from the wild to cultivated strawberries.

It is just as possible to conceive of the nematode as a native of that region as to conceive of the many native plants as having evolved there. It is equally plausible, however, to recognize the possibility of the pest having been introduced perhaps a hundred years ago when ships sailed from northwestern ports laden with lumber and other products and came back sometimes with dirt ballast from European ports.

The interesting fact must be recorded here that *Hypochaeris radicata* is, according to Piper and Beattie (*8*), a weed that is not native to that section. It is said to have been introduced from Europe. This fact naturally adds considerably to the interest of the problem, particularly in connection with speculation as to the origin of the disease and how it has become so widespread.

INOCULATION EXPERIMENTS.

Inoculations were made as a rule by the rough but effective method of simply breaking up diseased plants containing living nematode material—eggs, larvæ, and adults—and stirring them into the soil. Careful observations showed that this releases the organisms into the soil, from which they enter immediately any host plant they may be able to infest.

Shortly after the occurrence of the disease on cultivated strawberries in the Northwest became known in 1919, diseased specimens sent to Washington, D. C., were used to inoculate *Fragaria vesca*, *F. virginica*, *F. platypetala*, and *F. chiloensis*, all of which were successfully infected. No significance was attached to this at the time, however, except in possible relation to future studies on resistance. It was not until two years later that *F. chiloensis* was found naturally infested.

Inoculations of red-clover seedlings were made at Corvallis, Oreg., with the wild-strawberry material, and typical infections were secured. In Plate I, *D*, are shown typical diseased clover seedlings

that became affected as a result of such inoculations. Attempts to inoculate other hosts with the Hypochaeris strain have thus far failed. Further inoculation experiments, designed to get some information as to the possibility of these wild strains passing over to cultivated hosts, are under way at the present time.

ECONOMIC SIGNIFICANCE.

Many different crops are subject to infection by the stem nematode, according to foreign literature. Among these are alfalfa, barley, beans, buckwheat, flax, garlic, hyacinth, narcissus, oats, onion, peas, potato, rye, strawberry, and many others of less importance. Many of these crops are cultivated in western Oregon and Washington. The general belief in Europe is that there are distinct biological strains of the nematode. It is not known at the present time whether or not the American strains can adapt themselves to new hosts. The mere fact of the existence of the disease in so many hosts seems to imply this possibility.

SUMMARY.

The stem nematode *Tylenchus dipsaci* has been found rather abundantly in the Pacific Northwest on the wild strawberry (*Fragaria chiloensis*) and on the false dandelion (*Hypochaeris radicata*).

The wild-strawberry strain of nemas occurs along the west coast of Oregon near the seashore, from Coos County to northern Tillamook County. The Hypochaeris strain was found from the southern part of Lincoln County, Oreg., to Long Beach, Wash., being almost universally present in western Oregon.

Judging from natural occurrence, the two strains appear to be entirely independent of one another.

The symptoms of the disease on either host are swelling and crinkling of the leaves and stems, resulting in extreme cases in marked twisting and bending. Where an abundance of infection is present in the crowns the plants are often killed. In strawberry plants the stolons and the flowering parts are swollen and distorted also.

Several species of Fragaria are capable of becoming infested. The strawberry strain can be transmitted to red-clover seedlings. Attempts to transmit the Hypochaeris strain to other hosts have failed thus far.

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